Prognostics Through Ground/Flight Test

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What is “Flight Test”?

- A branch of aeronautical engineering consisting of collecting data on a vehicle during various phases of ground and flight and then analyzing these data for evaluation of characteristics. The purpose is to validate the design and safety aspects. This process supports two major tasks:
  1. Identifying and correcting design problems
  2. Providing verification and documentation of aircraft capabilities

- Flight testing can encompass a single system to an entire vehicle and included systems.
- Following the full scale flight test there usually is a follow on test program that further enhances the vehicles maturity as well as allow a platform for modernization. This can last many years following first customer utilization.

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Why Elevate Prognostics During Flight Testing?

- Aircraft and systems are exposed to flight regimes and loading conditions not normally encountered during standard operational use.
- Chance to really determine how system works during excursions outside the operationally designed envelope.
- Example – B777 nonresponsive to thrust commands. Aircraft landed short of runway @London Heathrow Airport.
- Sensors exist on aircraft within fuel and engine systems for temperature, Δ/pressure and flow rates.
- Aircraft is tested to limits that this event occurred within, flew at OAT's that flight manual stated.
- What wasn't there! Algorithms simply embedded within engine or avionics system that could have detected and prognosed the potential for ice to form on fuel line walls and advising the crew of the potential problems with the fuel system.
- Diagnostics and prognostics, not just for a single component failure.

A Good Reason to Look Forward!

Unfortunately this takeoff ended in an unrecoverable departure from flight. The aircraft was telling the crew something was wrong. It saw the departure but the crew didn't listen. Equally important is to USE diagnostics and prognostics correctly.

Two takeoffs, one operational and one an airshow practice. Both were also within the defined flight envelope of the aircraft at the time the aircraft left the ground.

VIPR 1 Test Program

Overall Test Objective:

Demonstrate multiple structural and gas path health management sensors in an operating engine environment. Integrate sensor / detection technologies with Structural and Gas Path diagnostics.

Approach:

Perform engine ground tests using high bypass turbofan engine. Conduct normal engine operations and also operations that have seeded mechanical and gas path faults (simulated).

Completed all VSST Test Objectives

- **Preservation Oil Burnoff**: simulated engine oil leak; emission sensor system located aft of the engine nozzle does correlate to the engine oil burn off event and, as expected, returns to a baseline
- **The Self Diagnostic Accelerometer** has been demonstrated for the first time in an aircraft engine
- **The μwave tip clearance sensor**: completed EMI/EMC testing with no major issues. This test clears it in regards to EMI for engine installation for the VIPR 2 phase.
- **Emission sensor system**: demonstrated system under nominal and seeded fault conditions and performed mapping of signals across the core and fan flow to help determine optimal placement. The ESS system in general tracked a wide range varying engine conditions.
- **Gas Path Diagnostics**: Confirmed that sensed engine gas path parameters of interest were consistent with analytical model predictions
- Inserted simulated faults to cause specific air flow bleed actuators to operate off-schedule in order to simulate faulted conditions
- A full sweep of the vortex formation from head on and 45° winds as a function of engine height above a ground plane was completed

VIPR 2/3

- NASA led and conducted at Dryden/Edwards test facility
- Scheduled to continue with increased industry and government partnering
- Areas of research will be:
  - Continuation of VIPR 1
  - Actual fault seeding and embedding in both gas path and mechanical systems
  - Harsh environment operations to include prolonged volcanic ash ingestion
  - Inlet dynamics research

Enhanced Prognostics Thru Virtual Sensing

- We're doing it already, why not expand the practice?
  - Example: Some engines utilize airframe air data in the event engine air data probe fail.
- Potential research areas lab thru flight test:
  - Hydraulic pressure sampled near an actuator could show a surface is jammed, binding, or damaged.
  - Comparison of GPS or inertial data to air data sensors can indicate large changes in winds or faulty air data systems
  - Engines could utilize airframe inertial data to note hard landing events that can be stressful on engine bearings
  - Inertial systems and fuel slosh models to log wing and possibly fuselage structural health
  - Acoustic sensors open multiple possibilities: Notice how you tell flaps are lowered, landing gear is down, or thrust reversers are deployed from changes in acoustics (preliminary research conducted)
- Modern aircraft and systems record multitudes of data. Why not mine that data to extract more information to enhance PHM?